

# Space and Missile Systems Center



## GPS Modernization Update

June 2014

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Global Positioning Systems Directorate

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# GPS Constellation

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- **Robust constellation**
  - 30 space vehicles currently set healthy
    - 6 GPS IIA, 12 GPS IIR, 7 GPS IIR-M, 5 GPS IIF
  - 5 additional satellites in residual status, 1 in test status
  - SV-6 successfully launched 16 May 14
- **6 more GPS IIFs in pipeline**
  - SV-7 scheduled for Jul 2014 launch
  - SVs 8 and 10-12 in storage; SV-9 pending final testing
- **Extensive International and Civil Cooperation**
  - Agreements with 57 international customers
  - ~2 billion civil/commercial users
- **Global GPS civil service performance commitment met continuously since Dec 1993**
  - Best performance 46.6 cm User Range Error (URE) 8 Jun 13; best weekly average 64.6 cm URE 16 Apr 14
  - Performance improving as new satellites replace older satellites

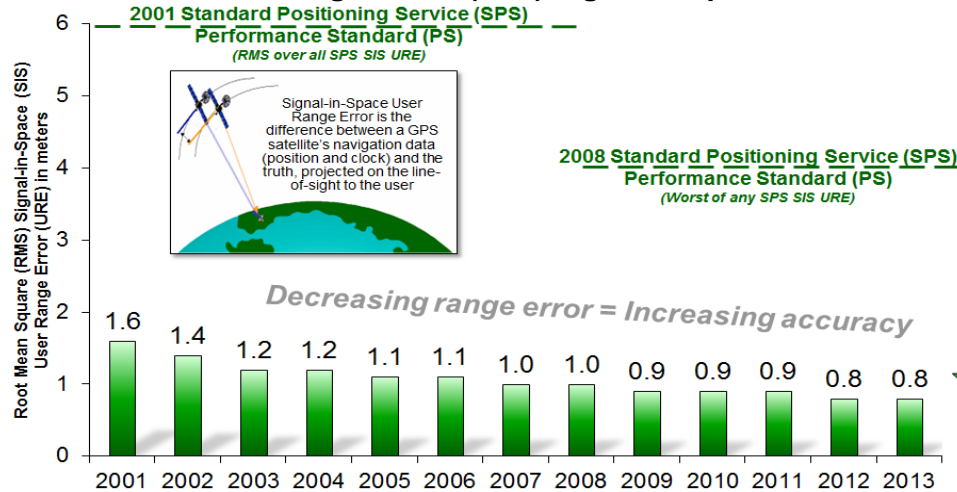




# GPS Signal in Space Performance

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## Standard Positioning Service (SPS) Signal-in-Space Performance



Mining and Construction



Precision Agriculture

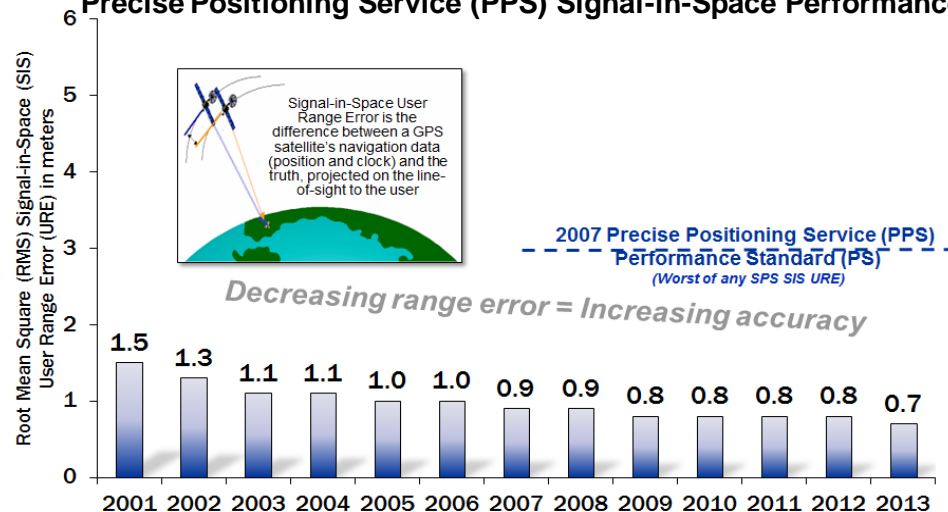


Aviation



Wildlife Research

## Precise Positioning Service (PPS) Signal-in-Space Performance



Precision Navigation



**System accuracy exceeds published standard**



# GPS Modernization Program

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## Legacy GPS IIA/IIR

- Single Frequency (L1)
- Coarse acquisition (C/A) code
- Y-Code (L1Y & L2Y)

## GPS IIR-M

- 2<sup>nd</sup> Civil Signal (L2C)
- M-Code (L1M & L2M)

## GPS IIF

- 3<sup>rd</sup> civil signal (L5)
- 2 Rb + 1 Cs Clocks
- 12 year design life

## GPS III

- 4<sup>th</sup> civil signal (L1C)
- 4x better User Range Error than GPS IIF
- Increased availability
- Increased integrity
- 15 year design life



## Legacy Operational Control Segment (OCS)

- Mainframe system
- Command & Control
- Signal monitoring

## Architecture Evolution Plan (AEP)

- Distributed architecture
- Increased signal monitoring
- Security & Accuracy
- Launch and disposal ops

## Next Generation Operational Control System (OCX) Block 0

- Launch & On-Orbit Checkout of GPS III
- Fly legacy constellation

## OCX Block 1

- Transition from OCS to OCX for all GPS command and control operations

**Increasing system capabilities - Increasing user benefit**



# CNAV Pre-Operational Deployment

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- Initiated continuous CNAV message broadcast (L2C & L5) on 28 Apr 14
- CNAV Data message uploaded twice a week initially; with daily uploads expected by Dec 2014
- Position accuracy not guaranteed during pre-operational deployment of CNAV signals; “use at own risk”
  - L2C message currently set “healthy”
  - L5 message set “unhealthy” until sufficient monitoring capability established (signal verification)
- Expected Performance for users:
  - During first 24 hours after upload, CNAV performs as LNAV
  - Expect divergence between CNAV & LNAV as CNAV data ages until next CNAV upload





# GPS III

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- Newest block of GPS satellites
  - 4 civil and 4 military signals:  
L1 C/A, L1C, L2C, L5; L1/L2 P(Y), L1/L2M
  - First satellite to broadcast common L1C signal
  - Three improved Rubidium atomic clocks
- GPS Satellite Simulator delivered to support Next Generation Operational Control System (OCX) & cross-segment testing
- GPS III Non-Flight Satellite Testbed accomplished launch processing at Cape Canaveral; reduced risk for integration & test and launch processing
- SV07/08 contract awarded 31 Mar 14



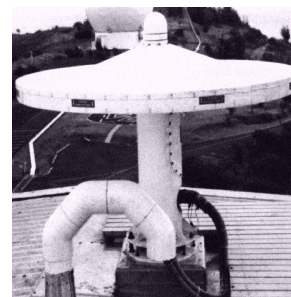
Lockheed-Martin (Waterton, CO) – Prime



# Ground Segment

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- Current system Operational Control Segment (OCS)
  - Flying GPS constellation on Architecture Evolution Plan (AEP) and Launch & Early Orbit, Anomaly, and Disposal Operations (LADO) software systems
  - Cyber security enhancements in progress
- Next Generation Operational Control System (OCX)
  - Modernized command & control system with M-Code, modern civil, signal monitoring, info assurance infrastructure and improved PNT performance
  - OCX Block 0 supports launch & checkout for GPS III and is in integration & test; Raytheon (Aurora, CO) - Prime
  - OCX Block 1 supports transition from OCS in 2017
  - Successfully completed 3 GPS III launch exercises



**Monitor Station**



**Ground Antenna**





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# Spectrum Allocation and Sharing Initiatives



# Spectrum Allocation and Sharing Initiatives

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- International & Domestic push to reallocate or share spectrum on L-Band for mobile services
- Domestically, Presidential Memo regarding providing 500 MHz of spectrum for mobile services
  - Adjacent-Band Capability (ABC) study initiated to ensure GPS receiver performance
- Internationally, working through the World Radiocommunication Conference to identify spectrum allocation opportunities and to ensure Global Navigation Satellite System (GNSS) performance

***Fully support the allocation and sharing of spectrum through robust analysis, testing and specification development***



# AFSPC Contribution to Adjacent-Band Compatibility (ABC) Study

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- Setup / provide representative receiver hardware to model interference scenarios
- Provide subject matter experts as required to conduct analysis & testing
- Use existing GPS public forums to involve receiver community

***Partnership with DOT to ensure successful spectrum allocation & sharing***



# International Spectrum Reallocations for Mobile Sources

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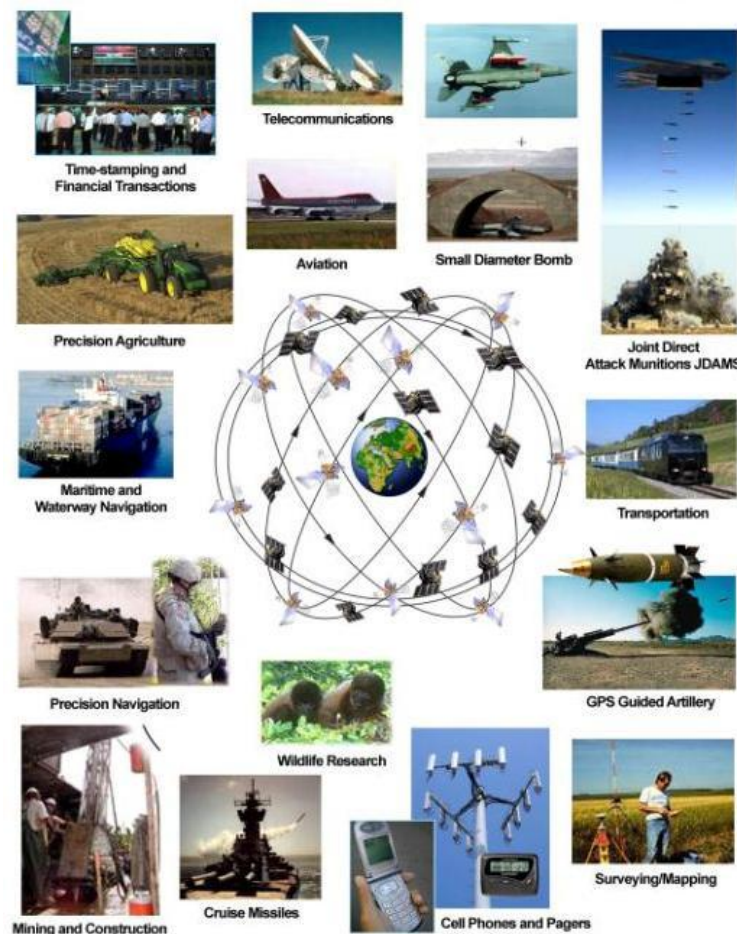
- Working through the 2012 World Radiocommunication Conference (WRC-12)
  - Consider additional spectrum allocations for the mobile service on a primary basis
  - Identify additional frequency bands for International Mobile Telecommunications (IMT) operations
- GPS Directorate Goal: monitor all GPS bands and adjacent bands being proposed as candidate bands for reallocation or sharing with IMT
- Various US agencies and international GNSS providers share this interest to help protect GPS



# GPS Summary

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- Modernized signal development in progress
  - 12 L2C, 5 L5 and 12 M-Code capable SVs on orbit
  - OCX will implement full C2 of L1/L2M, L2C, L5
  - Continuous L2C, L5 CNAV message broadcast began Apr 2014
  - Expect the first L1C SV launch in 2016
  - Continued progress to M-Code early use ~2017
- Modernization of all GPS Segments making progress but still with technical challenges commensurate with the advanced tech
- Working domestically, internationally and with Industry to simultaneously protect GNSS services and release spectrum for mobile services



***Maintaining the world's "Gold Standard" PNT service is Job #1***





# Backup

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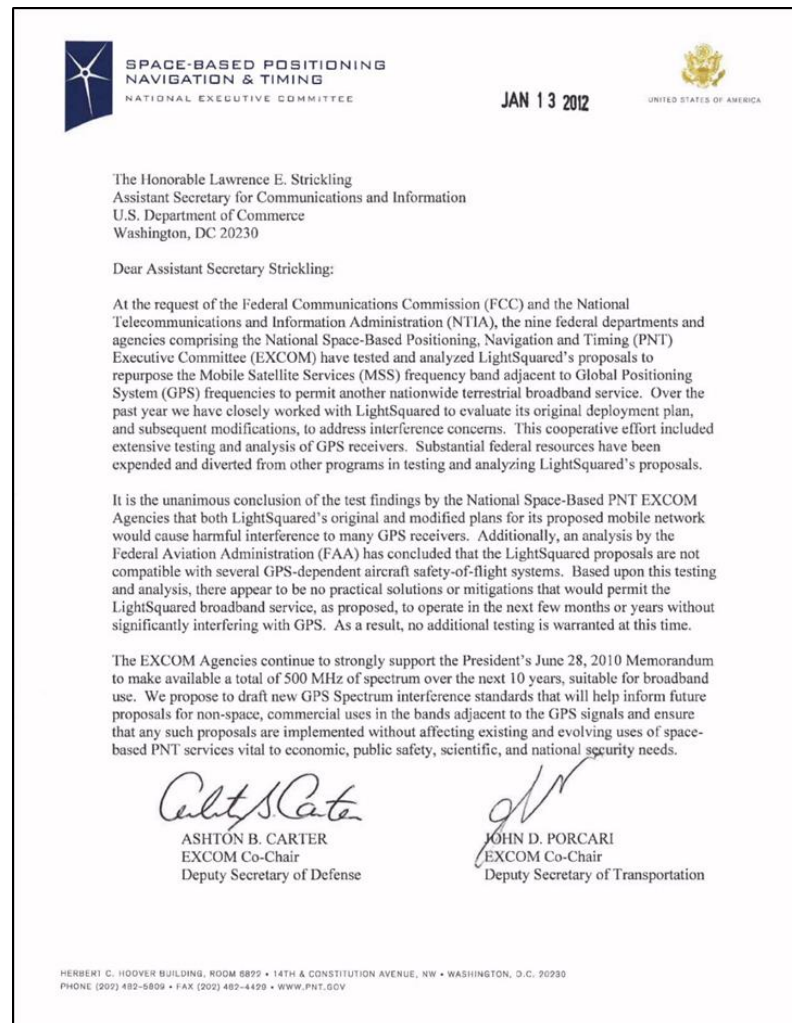


# Space-Based PNT EXCOM Spectrum Interference Standards

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- 13 Jan 12, National Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee (EXCOM) co-chair letter to National Telecommunications and Information Administration (NTIA) proposed to draft new Global Positioning System (GPS) spectrum interference standards:

- Inform future proposals for non-space, commercial uses in the bands adjacent to the GPS signals.
- Ensure such proposals are implemented without affecting existing and evolving uses of space-based PNT that are vital to economic, public safety, scientific, and national security needs

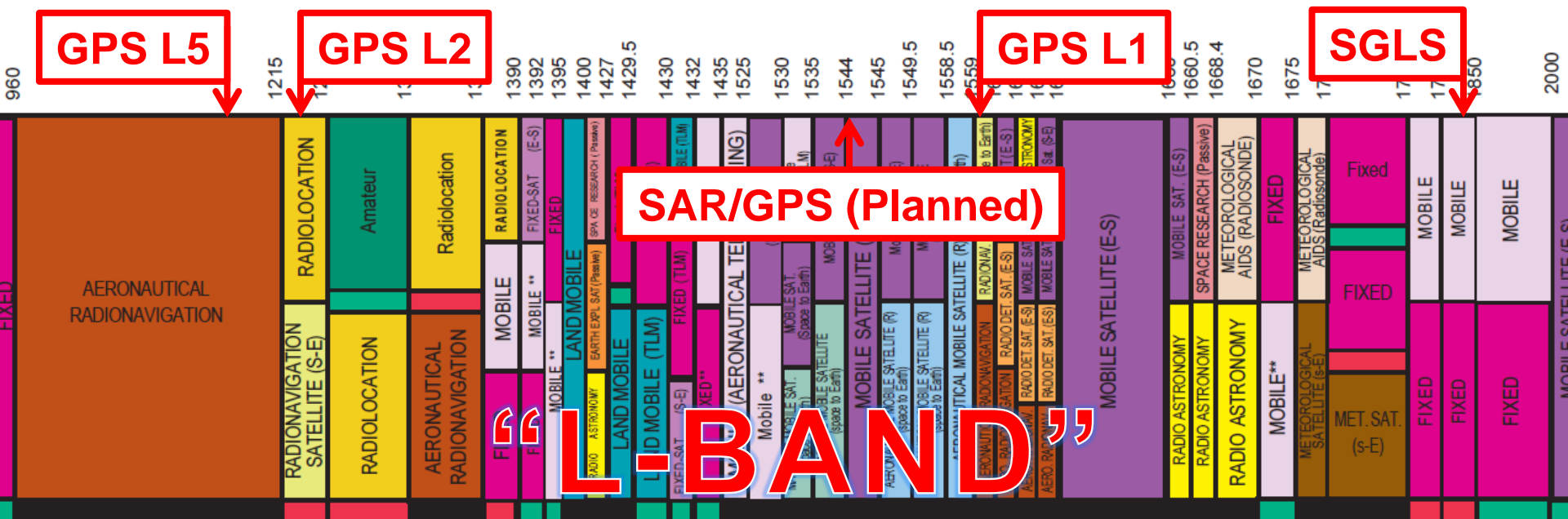




# Adjacent-Band Compatibility (ABC)

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- A signal's ability to operate free of harmful degradation (interference) from other transmissions in the nearby areas of the electromagnetic spectrum
- Adjacent-band interference (ABI) can occur as the result of an adjacent band's power and proximity to a signal as well as inadequate filtering and/or tuning



\*National Telecommunications and Information Administration (NTIA) Table of Allocations in the L-Band (1-2GHz, IEEE)



# LightSquared Background

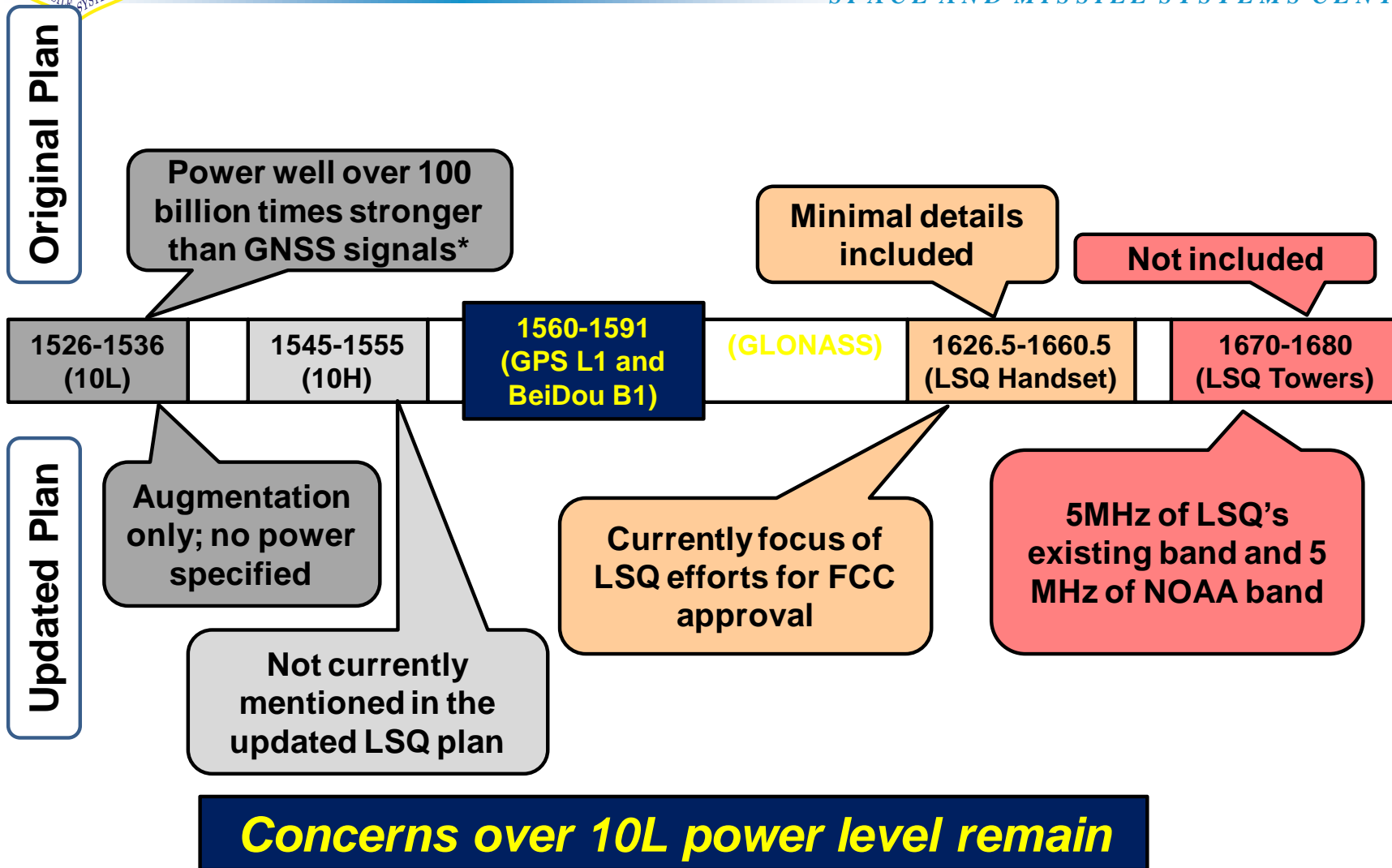
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- LightSquared (LSQ) – a company seeking to develop a 4G LTE wireless broadband system using a block of frequencies adjacent to GPS
- Timeline of LSQ evolution:
  - 2001 – Mobile Satellite Ventures (Satcom only with desire for ATC)
  - 2004 – FCC authorized Satcom with Ancillary Terrestrial Component (ATC)
  - Jan 2011 – FCC granted conditional waiver to offer increased terrestrial 4G service (40K ATC) only if harmful interference to GPS was resolved
  - Feb 2011 – Oct 2011 – Testing commences and LSQ begins to modify their operational plan as the results indicate negative impacts to GPS
  - Nov 2011 – Jan 2012 – Further testing and analysis is conducted on the various changes being made to the LSQ plan
  - Feb 2012 – NTIA memo to FCC declaring that LSQ will impact GPS services and that there is no practical method for mitigation at this time
  - 14 May 12 – LSQ filed for bankruptcy
  - Present – LSQ bankruptcy decisions on-going; handset plan moving forward with concerns expressed from Department of Transportation and other US federal agencies



# Real World Example: LightSquared (LSQ)

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\*Power at a distance of 100 meters from a LSQ tower